Weatherwise

Operation Moby Dick

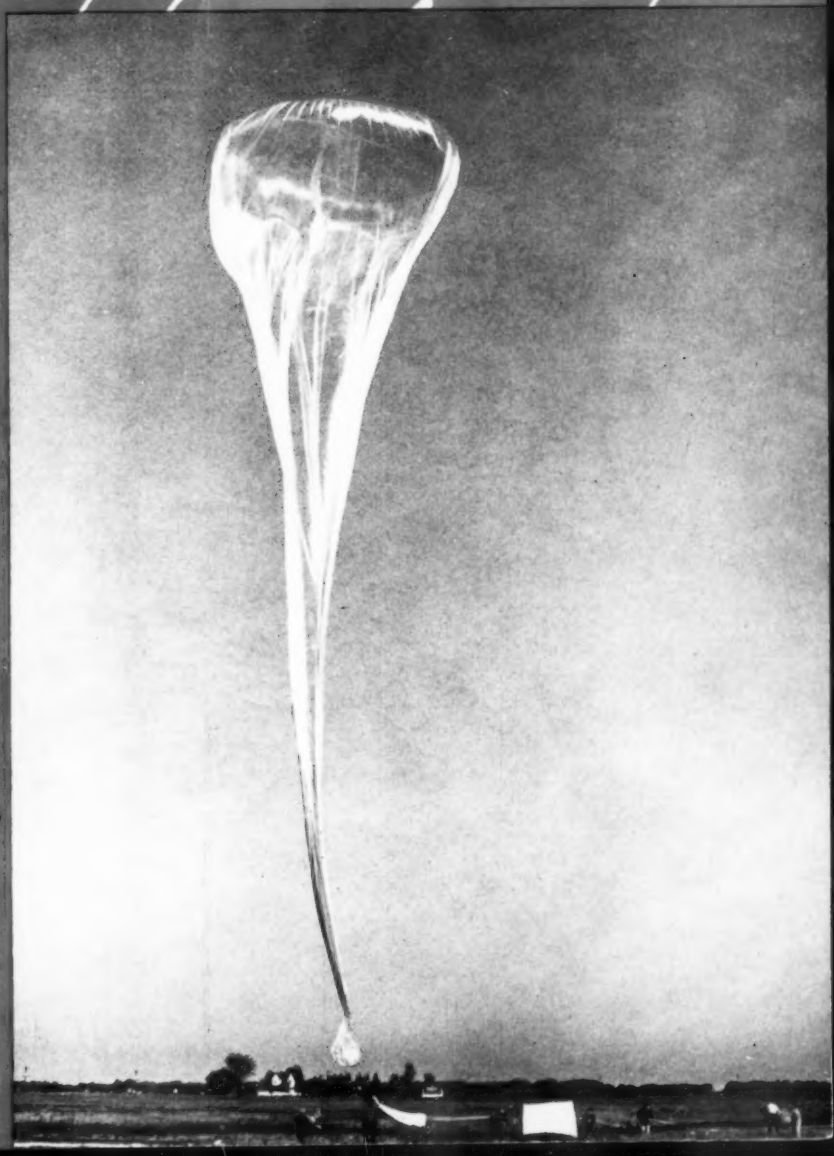
Snowfalls--
Paul Bunyan Style

Ice-Fog and Air-
craft Operations

AMS 113th Meeting

Philadelphia's
Greatest Snowstorm

Coldest Temperatures
in the United States



Vol. 4, No. 6
DECEMBER, 1951

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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AWA To Become Part of the AMS

THE Amateur Weathermen of America will be merged with the American Meteorological Society on January 1, 1952. At the same time the membership structure of the AMS will undergo a change authorized in a mail vote of the members taken in recent months. Two new member classifications in the AMS — associate and student — have been created, with the aim of broadening the base of support for the society's activities.

The Amateur Weathermen of America was founded five years ago to stimulate interest in the study of weather among laymen. The first phase of this program now draws to a close, and in the future the activities of the AWA will be carried out under the direction of the AMS. Present members and all interested amateur meteorologists are urged to take associate membership in the AMS, for which the yearly dues are the same as they have been in the AWA — three dollars per year.

Associate members will receive WEATHERWISE, and all notices and programs of the society, and will be privileged to attend AMS national meetings held four times annually and the local seminars held monthly in many large cities. They will be supporting the only national society devoted exclusively to promoting the science of meteorology. A description of the organization, aims, and publication program of the AMS will be mailed to all present AWA members in the near future.

The American Meteorological Society was first organized in 1919 as a result of the stimulus to meteorology provided by World War I. Twenty-five years later, during the second World War, the society was reorganized as a professional group, with both regular and professional memberships, to which the two new classes have now been added. The present dues structure is: Professional, $12.00, including *Journal of Meteorology*, *Bulletin* of the AMS, and WEATHERWISE; Regular, $7.00, *Bulletin* and WEATHERWISE; Student, $5.00, *Bulletin*

(Continued on page 127)

Vol. 4, No. 6 — December, 1951

CONTENTS

Operation Moby Dick 123

Snowfalls — Paul Bunyan Style
— A. H. Eichmeier 124

Ice Fog and Aircraft Operations
— Lt. George J. Gray, Jr. 128

Winter Strikes Early in 1951 131

American Meteorological Society 132

Philadelphia's Greatest Snowstorm— December 25-26, 1909
— Conrad P. Mook 134

Coldest Temperatures in the United States
— Arnold Court 136

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Cover: A Skyhook balloon, filled with helium, begins its ascent, carrying meteorological and cosmic ray recording apparatus into the stratosphere. This type of balloon will be used in Operation Moby Dick (see page 123). Photograph by General Mills Research Laboratories.

WEATHERWISE is published bimonthly at The Franklin Institute, Philadelphia 3, Pa., where its editorial and advertising offices are located. Subscription is $3.00 per year; add 50 cents for postage to Canada and all countries in the Pan-American Postal Union; add $1.00 for all other foreign countries. Beginning with Volume 5, the circulation and subscription offices are at the American Meteorological Society, 3 Joy St., Boston 8, Mass.

Inflating a Skyhook balloon at dawn. Photograph by General Mills Research Laboratories.

OPERATION MOBY DICK

THE STRATOSPHERE'S wind system will be subject to systematic probe these coming months. Weathermen of the Air Force will be engaged in *Operation Moby Dick*, a project to fly a series of controlled balloons across the United States at heights ranging from 50,000 to 100,000 feet. Heretofore, our knowledge of the wind flow at these altitudes has been somewhat sketchy, since we have had only momentary flights by airplanes, balloons, and rockets into this region.

Plans call for the establishment of bases on both the Pacific and Atlantic coasts. During this winter, balloons with constant-level control devices will be released at short periods into the prevailing westerlies. As they drift eastward across the continent, requiring four days or less for the trip, they will be under constant radio surveillance so that their positions and hence their speeds and directions can be checked at all times. As many as 20 balloons may be in flight at once.

During the summer, flights will be launched from Atlantic seaboard points in an attempt to get the balloons into the easterly current that is believed to prevail high in the stratosphere at that season. It is "contrary" winds of this kind that are of great importance in jet aircraft operations, making it imperative to increase our knowledge in order that winds in the stratosphere can be forecast with much higher accuracy.

The balloons will be of a type developed for the U. S. Navy in 1948, pear-shaped, plastic bags made of polyethylene, measuring 73 by 102 feet, white in color — hence, Moby Dick (see front cover). Some of them have risen to 120,000 feet. Even at 100,000 feet, the balloons are expected to be visible from the ground, and to reflect the colors of the sun at morning and evening twilight. In the event a balloon should tend to lose altitude and interfere with commercial aircraft, the ground observers can operate remote controls to drop its instruments by parachute and to explode the balloon.

A plow clearing a drift after one of Upper Michigan's heavy snowfalls. Michigan State Highway Department photograph.

Snowfalls — Paul Bunyan Style

A. H. EICHMEIER, U. S. WEATHER BUREAU, LANSING, MICHIGAN

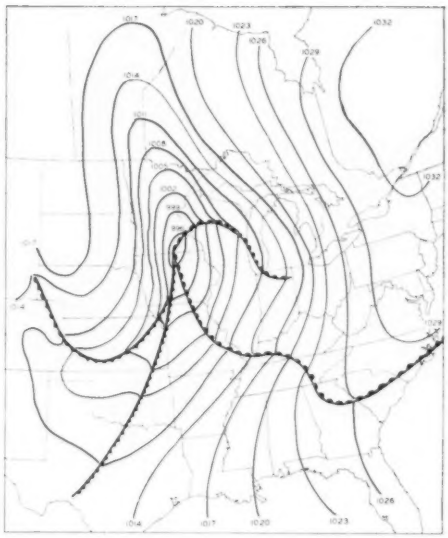
THE KEWEENAW PENINSULA, a narrow strip of hilly land jutting into Lake Superior from Michigan's upper peninsula, receives more snow than any other point east of the Rockies, with the exception of certain areas in New England and New York. It has been said that it snows in the Keweenaw Peninsula when there is a low to the south, or the wind blows from the east, north, or west. In other words, it snows most of the time in winter.

The records substantiate these impressions. At Calumet last winter there were 51 consecutive days with snowfall, from November 19, 1950, to January 8, 1951. At Houghton, the average number of days with snowfall during December, January, and February is 52, while at Escanaba, on the south side of the upper peninsula, the total is only 33. Even there the lake influence is in operation during east winds off Lake Michigan. Compare these figures with the records at Madison, Wisconsin, with only 24 snowy days during the three winter months, and at Minneapolis, Minnesota, with 23 snowy days.

January, 1950, was a month breaking all records for snowfall in the Calumet area, with 115 inches recorded. The total that winter was 125 inches, compared to 74 inches for the same period during the previous year. The worst blizzard in 11 years raged over the Keweenaw Peninsula on January 16th and 17th; in 12 hours the night of the 15th and early morning of the 16th 22.2 inches of snow fell. Winds reached 60 miles per hour. Traffic was at a standstill, and snowplows were unable to keep roads clear. In one case, snowplows crawled past a snow-covered automobile without its being seen. In the six-day period, January 15-20, 1950, 46.1 inches of snow fell at Calumet. There have been numerous other times, however, when over 30 inches have fallen in a period of six or seven days.

Nevertheless, although these individual storms are not rare, they do not occur as often as might be expected from the great amounts of snow piled up on the ground. Rather, it is the day-to-day accumulation which accounts for a goodly portion of the total. As can be seen from the snow contour map, the whole upper peninsula is a heavy snowfall area, with the greatest amounts just inland from the lake shore, where the lake effect is greatest. Lake Superior, although freezing during the coldest weather as far out from the shore as the eye can see, actually remains open over most of its surface. Thus, comparatively warm water is in direct contact with the coldest air, causing a rapid flux of moisture from the lake surface to the air, with the result that the temperature and humidity of the lower layers increase considerably in the long trip over water, and instability builds up.

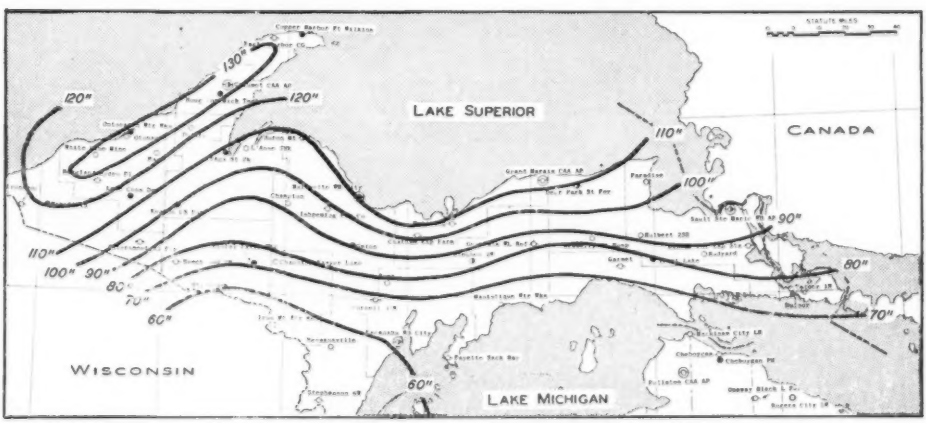
The typical synoptic situation favorable for heavy snowfall on the Keweenaw Peninsula is the same as that for other points in the region, that is, a well-developed low pressure area to the south with overrunning warm air. However, instead of precipitation caused only by the condensation in this overrunning air, a one-two-three punch is delivered to the Keweenaw Peninsula: first, by moisture from the east wind induced by the low pressure area to the south; second, by precipitation from the overrunning warm air; third, by condensation from the new cold air mass



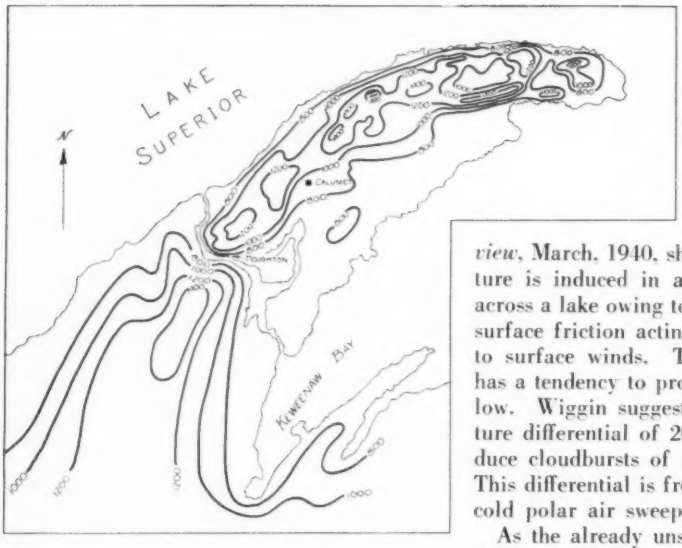
The synoptic map, 7:30 a.m. EST, January 15, 1950.

coming in from the west and northwest after the center of the low pressure area has passed eastward. The result is that it begins to snow earlier, falls in heavier amounts, and continues longer than if the fall were from overrunning air only.

In his article in WEATHERWISE, December, 1950, "Great Snows of the Great Lakes," B. L. Wiggin listed the following factors operating to produce heavy lake snowstorms, es-



The contours of this map of the Upper Michigan peninsula show the average annual snowfall for the period of record up to 1950, inclusive.



A topographical map of the Keweenaw Peninsula, the contour interval being 200 feet. The surface of Lake Superior is about 600 feet above mean sea level.

pecially with regard to the lee shores of the Great Lakes. These same factors should hold for Lake Superior:

1. A strong flow of cold polar air with a lee shore lapse rate adiabatic or greater to over 5,000 feet.

2. Cyclonic curvature to the flow pattern.

3. A large temperature differential between the air and water.

4. A long fetch over water.

5. A shear to produce longitudinal convective cells.

With a strong flow of cold polar air, C. G. Rossby and R. B. Montgomery[1] show that a lapse rate approximating the dry adiabatic will be established up to about one kilometer height in a wind current of 30 miles per hour, assuming the character of terrain that surrounds most of the Great Lakes. The action of the warm source will be to lift the inversion at the top of the turbulent layer from about one kilometer above the surface to about 2½ kilometers. This lift value is deduced from reports of the tops of the instability cloud decks in the lee of the Great Lakes.

J. J. George, in the *Monthly Weather Review*, March, 1940, shows that cyclonic curvature is induced in a cold air mass moving across a lake owing to the suddenly decreased surface friction acting as a refraction device to surface winds. The warming effect also has a tendency to produce a shallow thermal low. Wiggin suggests, also, that a temperature differential of 20° F. or more will produce cloudbursts of snow on the lee shores. This differential is frequently exceeded as the cold polar air sweeps across Lake Superior.

As the already unstable air comes in over the land surfaces, it is given an additional impetus upward by the elevation of the land. The greater the elevation the greater this push upward becomes, and air which is already at the dry adiabatic lapse rate requires little or no push to rise. This is an important factor in the Keweenaw Peninsula, which has ridges running its length and ranging up to 900 feet above the waters of Lake Superior. This rise takes place over a distance of only a few miles. Mt. Houghton, for example, has a sea-level elevation of 1,466 feet, 864 feet above the lake surface. The Cliff Range reaches 1,450 feet above sea level, and there are several other hills of approximately 1,400 feet. Air already unstable and forced to rise over these ranges is given an added upward movement and will continue to rise of its own accord as long as it is warmer than surrounding air at the same levels, causing cumulus type clouds and the typical snow-squall conditions.

The Michigan highway department tries to

HEAVY SNOWFALLS AT CALUMET, MICHIGAN

1937	February 20-23	29.0 inches
1938	December 23-31	38.5 inches
1940	March 13-15	21.0 inches
1942	December 9-13	31.0 inches
1945	February 13-18	30.0 inches
1947	February 2-9	34.0 inches
1950	January 15-20	46.1 inches

[1]"The Layer of Frictional Influence in Wind and Ocean Currents," III, No. 3, Papers in Phys. Ocean. M.I.T. and Woods Hole Ocean. Inst.

keep state highway No. 26 open, but not No. 41; these are the two main highways running through the peninsula. The counties involved have a tremendous snow-removing job, almost impossible financially if the highway department did not take into consideration the extreme variation of snowfall over the state. The cost is shared by making cash payments to those counties that received over 60 inches of snow in the previous season, the payments being proportional to the amount of snow and the number of miles of road kept open. The snow depths measured by the co-operative observers of the U. S. Weather Bureau are used in this apportioning process.

From the preceding account, readers not accustomed to such quantities of snow might form the opinion that the population of the region must be greatly discomforted by the rugged winters. To the contrary, this weather is taken in stride. The population is largely of Scandinavian and Finnish descent, of an ancestry that has lived in regions of long, cold winters. Great enthusiasm abounds for winter sports, for skiing and ski meets.

After all, this is the land of Paul Bunyan who, legend says, strolled the length and breadth of Michigan's upper peninsula performing prodigious feats. People steeped in the tradition of Paul Bunyan would hardly be easily discouraged by such a minor thing as 11 feet of snowfall a year!

"Can't find the houses for the snow." This scene in the middle of winter is typical in many towns and villages in the Keweenaw region of Michigan's snowbound upper peninsula.

AWA TO BECOME PART OF THE AMS

(Continued from page 122)

and WEATHERWISE; Associate (amateur), $3.00, WEATHERWISE.

WEATHERWISE will continue under the same editorship and management as since it first appeared in February, 1948. No change in format or editorial content is contemplated. The editorial offices will remain at The Franklin Institute in Philadelphia, which has been the home of the Amateur Weathermen of America since its organization.

Weatherwatch has been discontinued with the October, 1951, issue, because of the greatly increased demands of defense work on the present editor's time. Some of the former *Weatherwatch* material will be included in modified form in WEATHERWISE, but those who wish to follow the current weather closely are referred to the Weather Bureau's weekly *Weather and Crop Bulletin*, which carries much material of this type.

The educational program of the AWA in the schools of the country will be continued under the guidance of the AMS. It is hoped that further resources will soon be available to expand the study of weather in high school science clubs, a program that has been formulated eventually to reach 25,000 schools in various regions throughout the United States.

Under the new arrangement, all membership correspondence and WEATHERWISE subscriptions for 1952 should be addressed to the American Meteorological Society, 3 Joy St., Boston 8, Massachusetts. This central office will give very efficient service to all members and to subscribers to this publication.

Ladd Field in Alaska, where under certain circumstances ice fog presents a hazard to the landing of aircraft. Photograph by the U. S. Air Force.

Ice Fog and Aircraft Operations

LT. GEORGE J. GRAY, JR., HEADQUARTERS, AIR WEATHER SERVICE

ICE FOG is relatively new as an aviation problem, but like most meteorological headaches it is not a new phenomenon. Until recent years, few people traveled in the isolated regions in which ice fog commonly forms. Therefore, even today we know very little about ice fog in its purest state.

We know that it forms by sublimation of the water vapor in the air, that is, the vapor in the air changes directly into ice without going through the liquid state. In pure form, ice fog has been observed by a few polar explorers, perhaps some prospectors, and lately by pilots who have flown over the barren wastes of the Far North. We know now that pure ice fog is a fairly common occurrence in central Alaska, Siberia, and northern Canada. It generally forms first in valleys and low places as soon as the wind calms down after the invasion of a moist air mass.

Thousands of observations made in Siberia have shown that some ice crystals occur in temperatures below about −5° F. Although there is a slight hump in the curve of frequency of ice occurrence in fog at about 15 degrees below zero, pure ice fog is not common above the temperature range of −40° to −60° F.

If ice fog formed only in the purest state described above, it would present little flying hazard, if any. Even in the interior of Alaska, temperatures of −60° F. are rare except in low spots during extended periods of extremely cold weather. In recent years, however, ice fog has become a nuisance and sometimes a hazard at some of our airfields in Alaska. At these inland bases, smoke from the housing areas and mess halls facilitates the formation of ice crystals at higher temperatures.

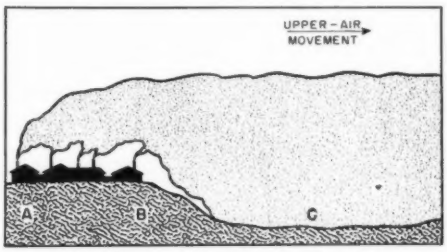
When smoke is present in the air, when there is a strong temperature inversion over an area (as frequently happens), and the wind is very light (less than three miles per hour), ice fog may form at temperatures of −40° F. to −20° F. Thus, when the temperature falls below −20° F., the smoke of

even a small village will cause ice fog in the village itself and for a few hundred yards on the downwind side. As the temperature continues to drop, the fog thickens and spreads farther afield downwind of the chimneys. The fog will persist as long as the temperature remains below −20° F. and the skies remain clear; this may be as long as 15 days at a time during a very severe cold spell.

In the course of a normal arctic winter, an inland airfield may be closed for about 25 days if there is a smoke pollution source nearby, such as a town or a highway with automobile traffic. At times the balance between no ice fog and its occurrence is so delicate that a two-engine plane warming up at one end of a runway can cause immediate formation of the fog, and produce a subsequent lowering of visibility from unlimited to below ½ mile within a matter of minutes. The common belief is that the exhaust from the engines introduces nuclei and water vapor into the air to initiate the formation of fog.

When ice fog is thin (visibility one to six miles), the ice crystals sparkle in the sun or moonlight. As it becomes thicker, ice fog takes on the dull appearance of ordinary fog as seen by an observer on the ground. Since ice fog never extends very high, vertical visibility is often good even when horizontal visibility is very restricted, and this represents the main flying hazard of ice fog. With a visibility of one mile reported at an airfield, a pilot 20 miles away at an altitude of 6,000 feet can clearly distinguish objects on the field; and when he is circling over the field, he can clearly see everything below him. On final approach, practically everything is still visible. It is only in the last hundred feet above the field that visibility drops to the one mile reported by the observer on the ground. With denser fogs, however, although there is still good vertical visibility, sight at an oblique angle is so impaired as to constitute a definite flying hazard. Landing is somewhat safer at night than during the day, because airport lights usually remain visible through even a fairly dense ice fog.

If there is a smoke pollution source, the wind is calm, and the temperature drops toward −20° F., there is an excellent chance that fog will form as soon as the sun sets. The air immediately above the ground cools by contact with the surface, owing to radiational heat losses, particularly on nights when no clouds are present to absorb and radiate the heat back to earth. Under these conditions, the ground is free to cool rapidly, and the air in the lowest layers soon becomes considerably cooler than the air several hundred feet above the ground. Thereby a surface inversion is established, which is nearly always present during arctic nights and often persists during the short winter days. This relatively strong inversion may extend to 2,000 feet. Frequently, the temperature at altitudes of 1,000 or 2,000 feet is 15° F. higher than it is at the surface. In Greenland at BW-8, a difference of 40° to 50° is not uncommon during winter. Because of the very stable lapse rate in the layer near the surface, there is little vertical mixing below the inversion.



Ice fog may form over a housing area (A) when the surface wind is calm or very light. It drifts in the direction of the wind flow at upper levels or downhill due to katabatic winds (B). It becomes most dense in low areas (C) but is never very deep; its top is fairly level due to temperature inversion.

This stability is important, since it serves to confine smoke and other pollutants to the layer below the inversion, so that the smoke drifts and spreads to cover a fairly large area. The smoke from one stack can affect an entire airfield. At Ladd Field in Alaska, this effect has been observed from the control tower, which extends above the layer of smoke and fog. An observer in the tower was able to see the smoke from one stack spread out to obliterate the entire air base. Under these conditions, smoke is not the only restriction, for ice fog will form as soon as the conditions described above are met.

Topography also has an important effect

on the ice fog problem. If the station lies in a very low spot, the fog concentration will be greater since the fog is confined by terrain. Under calm conditions, with the surface air considerably colder than the air a few hundred feet up, ice fog will flow downhill. Radiational cooling will cause the air in close contact with a hillside to become colder and therefore denser than the air at a corresponding altitude over an adjacent valley, because the air at the same level over the valley is not in contact with the cooling earth's surface. As a result, the heavier air on the hillside drains down the slope. This is known as a katabatic wind.

Forecasters in Greenland report that they have occasionally observed ice fog flowing lazily across the airfield at BW-8. At this base, the airstrip lies between a mountain range and a fjord not far from the ice cap. Cold, dry air drains down from the cap, carries the fog away from the field and tumbles it into the fjord like a slow-motion waterfall. The airstrip itself is not affected by fog.

Cold air drainage will continue to operate as long as the wind is sufficiently light to be offset by the local temperature effects. If the wind increases to about four miles per hour, it causes turbulent mixing so that the stability of the air below the inversion is upset. Cold air drainage will also continue as long as the ground continues to cool. This condition may persist for a period of days or weeks in arctic regions during winter, when the sun is at a very low angle, depending on clear nights and light winds.

In recent years control of ice fog has become an affair of some concern to the Air Force. There is not much that anyone can do about keeping the temperature above the critical level, but there are some preventive measures regarding smoke that can be taken. Some people have noticed that the smoke from oil heaters does not have as much effect on the formation of ice fog as does coal smoke. Others have suggested that electrostatic precipitators might be installed in the larger smokestacks, for use only in cold spells, in order to remove some of the particles on which fog forms. The big consideration, however, has been the direction of cold air drainage relative to the location of heating plants and other smoke pollution sources. The best place to erect a smokestack from this point of view would be downhill from an airfield. The airstrip itself should not be located at the lowest point in the valley, because there the smoke and fog will be densest.

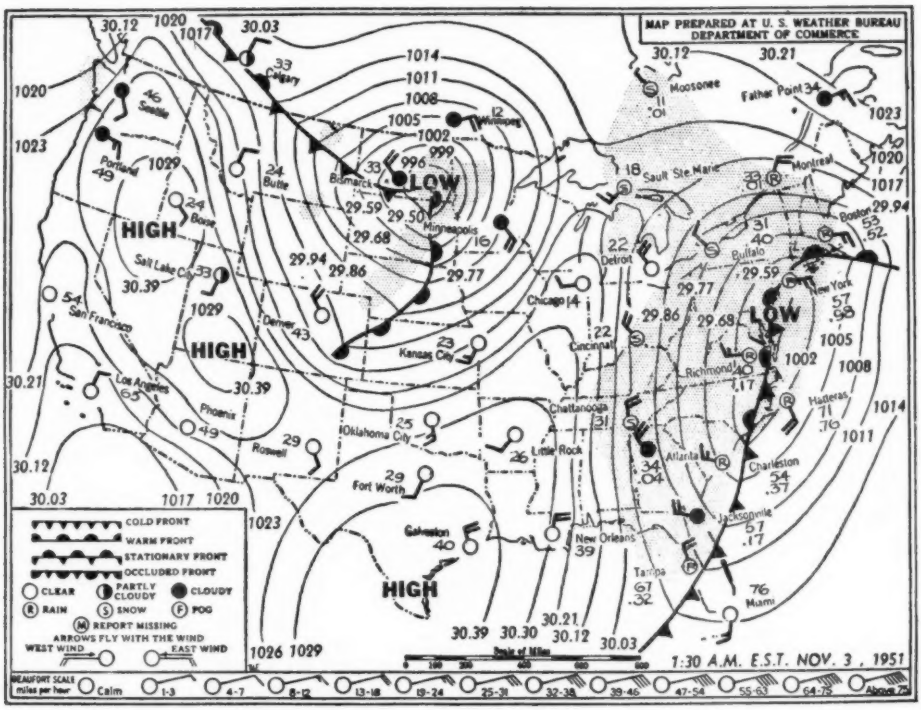
Ice fog disappears with a change in air mass, and even within the same air mass it may dissipate or at least thin out after a period, if any one of several circumstances or combinations of the circumstances arise. Diurnal heating, for example, will tend to break up the inversion and release the confined smoke and fog over a larger area. An increase in the surface wind speed will do the same thing. Often a mere change in the wind direction will spread the fog out over a greater area and thereby increase visibility. The formation or thickening of clouds will tend to stop the heat loss of the ground and prevent the continued formation of fog. As the crystals already formed settle, the visibility will increase.

RAINMAKING DAMAGE CLAIMS

Last year the city fathers of New York were spending money to make it rain. This year they are spending money to show that it did not rain. Damage claims amounting to $2,138,510 have been filed by government agencies and individuals in the Catskill area where Dr. Wallace E. Howell, of Harvard University, was engaged in rainfall stimulation activities from February through November, 1950.

A total of 169 claims includes one of $387,500 by the County of Ulster, which states that the excessive rainfall was caused by Howell and that the county's large road repair bill should be borne by the City of New York. The Town of Shandraken claims that Howell caused "a violent precipitation of rain resulting in severe flood in the Esopus Creek," and that the city was guilty of trespass and of "interfering with atmospheric conditions."

At least one trial suit is expected before the time for filing suit expires — a year and a month after the damage, November 25, 1950, the day of the great windstorm in the Northeast. Legal authorities look forward to handling the claims and suits as representing an entirely new field of legal interpretation.



A weather chart for 1:30 a.m., Saturday, November 3, 1951. The first cold air outbreak has just reached the Atlantic Coast, while the second will follow the deep low over North Dokota.

WINTER STRIKES EARLY IN 1951

WINTER made an unusually early appearance to most of the United States during the first week of November this year. In direct contrast to the mild conditions existing just a year before, the early onrush of polar air set new early season records for snowfall and cold throughout much of the Middle West, South, and Middle Atlantic states.

The cause was a large upper-air trough of low pressure that extended from the Hudson Bay area southward into the eastern states. Cold air poured down the western side of the trough in persistent surges on the wings of northwest gales. When the cold front stalled over Texas and the southeastern states, successive waves formed on the front drawing tropical air northward up over the dome of cold air, and the result was very heavy rain and snow over a large area from Texas northeastward to New England.

At the beginning of the month, a high pressure area was centered over Montana (30.83 inches) with a surface trough along the Atlantic seaboard. The temperature had fallen to —29° F. at Summit, Glacier National Park, Montana, where 35 inches of snow was on the ground. On November 2nd, polar air pushed rapidly southeastward, bringing below zero temperatures to Colorado and New Mexico, freezing to the Gulf coast of Alabama. The lowest reading at map stations was —7° at Fargo, North Dakota, and Trinidad, Colorado, and there was a newspaper report of —11° at Grantsburg, Wisconsin.

On Saturday, November 3rd, the season's first snow fell over a large area in the East and South. Arkansas reported a six-inch fall; Alabama had its earliest snowfall in history; Buffalo and adjacent lake points received eight inches, and New York City had enough to cover the ground. The snow occurred on a weekend of many major football games, making gridirons treacherous for players and roads hazardous for spectators. The weather map of 1:30 a.m., Saturday, wore a particularly wintry aspect with two active centers of low pressure, one in North Dakota and one at Philadelphia.

Rainfall was very heavy along the entire Atlantic seaboard as the two waves moved northeastward and brought in warm, moist, maritime air. New York City had four inches from two

(Continued on page 141)

AMERICAN METEOROLOGICAL SOCIETY

NOTES ON THE 113TH NATIONAL MEETING

MORE THAN 200 members and friends of the American Meteorological Society attended the 113th national meeting at Minneapolis, Minnesota, on October 9-11, 1951. The meeting was sponsored by the local seminar of the AMS with the co-operation of the Institute of Technology, University of Minnesota. This marked the first meeting in several years in the north-central states. Appropriately, many of the papers and discussions were devoted to the practical economic problems facing this great agricultural region.

Sessions were devoted to aeronautical meteorology, cloud seeding, industrial meteorology, bioclimatology, climatology, and agricultural meteorology. The session on cloud seeding attracted most interest, not only among the visiting meteorologists but from the local businessmen, since the prosperity of the entire Minneapolis marketing area is so dependent on a steady source of rainfall. Most of the principal commercial cloud seeders were in attendance.

Among the cloud seeders on the program were Dr. Wallace E. Howell, Cambridge, Mass., Dr. Robert Elliott, Pasadena, Calif., Dr. Bernard Vonnegut, Schenectady, N. Y., Dr. Irving Krick, Denver, Colo., and Paul B. MacCready, Jr., Pasadena, Calif.; all have been engaged in research or commercial seeding. The most optimistic of these claimed precipitation stimulation up to 50 per cent of the expected rainfall.

Criticism of the mathematical analysis methods of the cloud seeders was expressed in two papers. Sol Resnick, of Colorado A. & M. College, applied the isopotential method of analysis to seeding efforts in Colorado last spring and found no positive correlation in this particular case. Dr. H. C. S. Thom, U. S. Weather Bureau, concluded

Members and guests at the 113th national meeting of the American Meteorological Societ

the session with a presentation of a method of statistical analysis that he felt would put the entire subject on a sound mathematical basis.

One of the highlights of the meeting was a talk by Clint Youle, whose twice-a-week weather telecasts over the CBS network have made him a national figure. Mr. Youle described the trials and tribulations of his early days on television and how he received valuable criticism and coaching from his family at home. Weather fans are apparently great letter writers, as Mr. Youle receives hundreds of letters inquiring about all aspects of the weather. He believes that television can do much for the forecaster by bringing him into closer touch with his audience, thus enabling the public to understand some of the problems that face the average Weather Bureau forecaster.

On Wednesday evening a banquet was held at the Curtis Hotel. This was preceded by a cocktail party given for AMS members and their guests by General Mills, Inc., who are the designers and manufacturers of the Skyhook balloons to be used on Operation Moby Dick (see page 123). Several balloons were on display. The principal speaker at the banquet was Dr. Clyde Bailey, dean of the department of agriculture, University of Minnesota. Dr. Bailey spoke about water and its importance to the economy of the area.

AMS NEW YORK MEETING

The 114th national meeting and 32nd annual business meeting of the American Meteorological Society will be held in New York City January 28-31, 1952, with all technical sessions and special banquets at the Roosevelt Hotel, Madison Avenue and 45th Street. It is planned to have a science exhibit. Louis Harmantas, USWB airport station, LaGuardia Field, is chairman of the program committee; other members of the committee are Arthur Merewether, American Airlines, and Dr. Jerome Spar, New York University.

logical Society at the Curtis Hotel, Minneapolis, October 10, 1951. Schawang photograph.

PHILADELPHIA'S GREATEST SNOWSTORM — December 25-26, 1909

CONRAD P. MOOK, U. S. WEATHER BUREAU DISTRICT FORECAST CENTER
WASHINGTON NATIONAL AIRPORT, WASHINGTON, D. C.

ANY DISCUSSION of the possibilities of a white Christmas at Philadelphia, Pennsylvania, brings to mind in the memories of older residents a storm to them even more severe than the blizzards of 1888 or 1899. On the night of December 25-26, 1909, a snowfall of nearly two feet all but paralyzed the entire City of Brotherly Love. The staggering effects of the sudden storm, which developed that night along the Atlantic Coast, were felt from the eastern shore of Maryland to New England, as northeasterly gales accompanied by high tides created havoc in the coastal shipping lanes.

The day before Christmas, Friday, the 24th of December, was sunny in Philadelphia, and the temperature had risen to 40° F. during the afternoon. The morning and evening weather maps for the day (Fig. 1a and 1b) show a high pressure area moving eastward over the eastern United States. Following this high, however, was an area of low pressure accompanied by considerable rain and snow, which spread in advance of it over the Ohio Valley.

On Christmas morning (Fig. 2a) the low had reached northern Indiana, and shortly after 9 a.m. light snow began to fall in Philadelphia. If the low and its associated frontal system had continued to move in accordance with their previous displacements, the snow might either have stopped or changed to rain by nightfall. The snow continued all day, accumulating to 4½ inches by 8 p.m., and it became evident that the fall would continue during Christmas night.

The fall became heavier and the northeast wind increased, indicating the possibility that a new low, which was nowhere in evidence on the earlier charts, had now formed somewhere to the southeast along the coast. The weather map (Fig. 2b) shows vividly the explosive nature of the storm development which had taken place over the Delaware Breakwater area.

By midnight, only four hours later, the storm became so severe that, in the words inscribed in the official Weather Bureau records, "all efforts to keep traffic moving were unavailing." Streetcars became blocked in all parts of the city, and in some cases passengers spent the night in them. By morning railroad men who had struggled valiantly to keep the trains moving were forced to give up.

The snow had ended by 8 o'clock in the morning on December 26th (Fig. 3), but 21 inches of snow had fallen in 23 hours. During the three days that were required to reopen the streetcar lines, stocks of many foods and other supplies were depleted, and milk soared to 15 cents a quart, considered an enormous price in those days. Coal deliveries were almost impossible for many days, and this resulted in much suffering several days later when a cold wave dropped the temperature to 10° F.

Although Philadelphia was hardest hit of all major cities, there were others, such as New York, Baltimore, and Albany, where

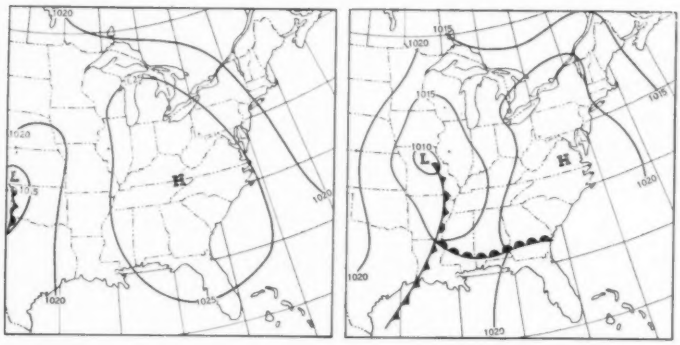


Fig. 1. The weather situation over the eastern United States on December 24, 1909, at (a, left) 8:00 a.m. EST, and (b, right) 8:00 p.m. EST.

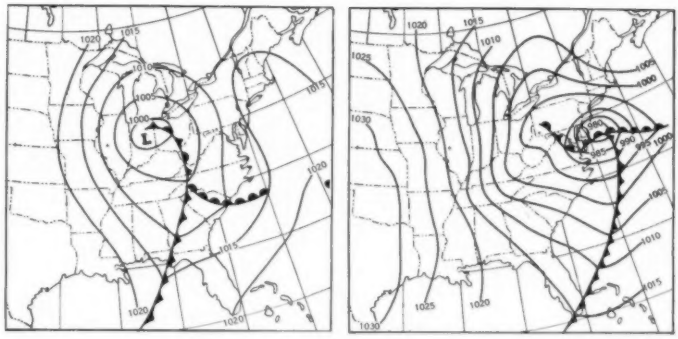


Fig. 2. The weather situation over the eastern United States on December 25, 1909, at (a, left) 8:00 a.m. EST, and (b, right) 8:00 p.m. EST.

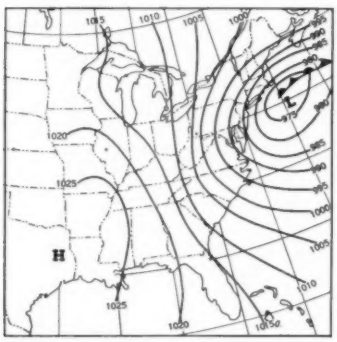
10 inches of snow fell, and Boston had a foot of new snow during the storm. Traffic of all kinds was slowed to a near standstill throughout Pennsylvania and much of the Northeast. Gales accompanying the coastal low caused considerable damage to coastwise shipping. Two coal ships out of Newport News were wrecked, one, the *S. S. Thurmond*, running aground 25 miles north of Atlantic City, its survivors reaching shore on a breeches buoy. The other, the five-masted *Davis Palmer*, went down in Massachusetts Bay with her entire crew of 12 men. As the gales coincided with the full moon, the high tide in Massachusetts Bay broke a record set in April, 1851. In the Boston area two persons were drowned and 2,000 made homeless by the tidal floods.

Forecasters reading this article may wish to compare the 1909 situation with that of December 11, 1944, described in the *Journal of Meteorology*, June, 1946, by James E. Miller, of New York University. The 12-hour pressure change chart for the morning of December 25, 1909, is shown here (Fig. 4) to facilitate such a comparison.

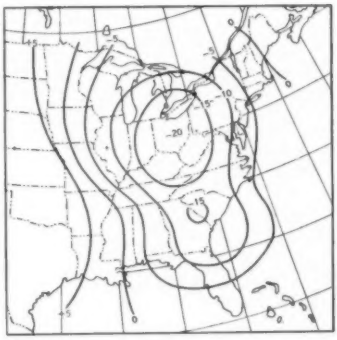
The account of this 1909 storm, like that of November, 1913, which the writer described in WEATHERWISE, December, 1949, is taken from a catalog of heavy snowstorms. This is filed for reference to assist forecasters at the Weather Bureau's District Forecast Center, Washington National Airport, in improving their score with the Atlantic Coast snowstorm.

USWB SERVICES SEPARATED

The Division of Climatological and Hydrologic Services of the U. S. Weather Bureau was organized in 1946, but because of the increasing importance of each of these fields they have been separated into two divisions, effective October 1, 1951. The new Climatological Services Division, during its reorganization and development, will be directed by W. F. McDonald, who also continues his regular work as assistant chief of bureau for administration. William E. Hiatt has been selected as chief of the Hydrologic Services Division.



LEFT: Fig. 3. The weather situation over the eastern United States for 8:00 a.m. EST, December 26, 1909.



RIGHT: Fig. 4. The 12-hour pressure change chart for 0730 EST, December 25, 1909.

Coldest Temperatures in the United States

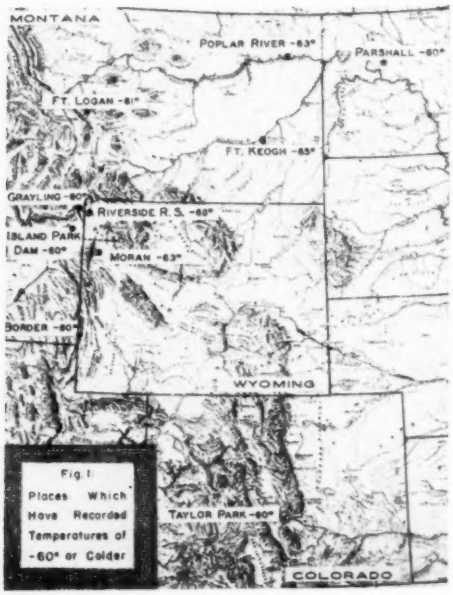
ARNOLD COURT*

TEMPERATURES of 60 degrees below zero Fahrenheit or colder have been recorded officially only 10 times in the United States, the latest being on February 1, 1951, at Taylor Park, Colorado. Each of these 10 observations was made in a different place, and only two occurred in the same year, on the same day in 1933 at two stations only 70 miles apart, as shown by the table.

Date	*Station*	*Temp.*	*Elev.*	*Operation*
1885, January 1	Poplar River, Mont.	−63°	1,994	1882-1889
1888, January 13	Ft. Keogh, Mont.	−65°	2,530	1877-1891
1899, February 11	Ft. Logan, Mont.	−61°	4,750	1870-1908
1905, February 12	Grayling, Mont.	−60°	6,700	1904-1912
1929, February 8	Border, Wyo.	−60°	6,085	1902-cont.
1933, February 9	Moran, Wyo.	−63°	6,770	1911-cont.
1933, February 9	Riverside Ranger Stn., Wyo.	−66°	6,700	1905-1933
1936, February 15	Parshall, N. D.	−60°	1,929	1931-cont.
1943, January 18	Island Park Dam, Ida.	−60°	6,300	1943-cont.
1951, February 1	Taylor Park, Colo.	−60°	9,206	1942-cont.

The temperatures are in Fahrenheit degrees, the elevations in feet above mean sea level, and the total period of operation of each station is given. These 10 coldest temperatures in the United States have been identified and investigated as part of a program to establish the extreme temperatures likely to occur in various parts of the world, so that equipment may be designed and tested for operation under all probable climatic conditions.

A definite regional concentration is apparent in these lowest temperatures (Fig. 1). The first three were observed at Army posts (active or abandoned) along rivers in central and eastern Montana late in the 19th century. Five were made within 25 miles of the western boundary of Wyoming, in valleys between 6,000 and 7,000 feet above sea level. The remaining two are anomalous, one on the plains of west central North Dakota, and the most recent in a valley in central Colorado more than 9,000 feet above sea level.



Six readings occurred in the seven-day interval from February 8th to 15th. Whether this is characteristic of extremely low temperatures is not certain. At the two places of these 10 where records have been kept long enough for analysis, the number of times that the coldest temperature of each winter occurred in the various months were:

	Dec.	*Jan.*	*Feb.*	*Mar.*
Border, Wyo.	8	22	15	1
Moran, Wyo.	7	18	11	2

Temperature ranges on these 10 days were very large. At Ft. Logan, the records indicate a spread of 79 degrees, and at Taylor Park, 63 degrees. Furthermore, the very low readings did not come during protracted cold

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spells, but represented falls of from 30 to 80 degrees below the maximum of the previous day, as shown by the temperatures listed here. Nevertheless, each of the low readings came during a period when temperatures generally were far below "normal."

As documented below, all 10 of these temperatures have been verified from the records of the original observations. Except possibly those in 1885 and 1888, all appear credible in that they were recorded during periods of extreme cold when other places in the same areas reported around −50° or colder.

In some cases, these readings may not reflect the air temperature at the standard height of five or six feet above the surface, because of snow accumulated under the shelters. On the respective dates, the following snow depths were noted: Island Park Dam, 42 inches; Moran, 40; Riverside Ranger Station, 38; Border, about 22; Grayling, 14; Parshall, 12; and Poplar River, 2. Snowfall data indicate only a few inches on the ground at Ft. Logan and Ft. Keogh. The snow depth is not available for Taylor Park, but from data for seven other places within 100 miles and more than 8,000 feet above sea level, it is estimated on the basis of the January precipitation of 1.30 inches at Taylor Park that there were 20 to 25 inches of snow on the ground there.

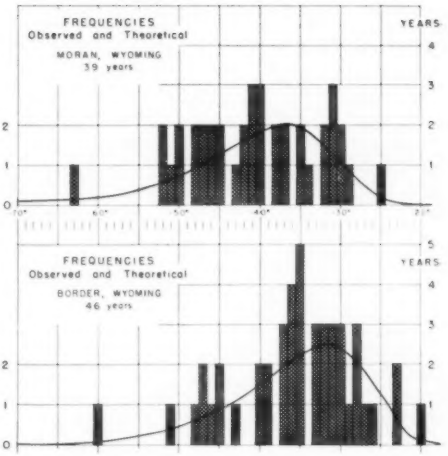

Fig. 3. The frequencies of the lowest winter temperatures at Moran and Border. The shaded blocks are the actual observed frequencies, and the solid curves are frequencies predicted from the statistical theory of extreme values.

TEMPERATURES BEFORE AND AFTER READINGS OF −60° OR COLDER

	− 2 DAYS		− 1 DAY		RECORD		+ 1 DAY		+ 2 DAYS	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Poplar River, Mont.	−36	−20	−45	−33	−63	−26	−26	+13	−13	+28
Ft. Keogh, Mont.	−10	+28	−34	−33	−65	−20	−41	−23	−46	−12
Ft. Logan, Mont.	−24	− 1	−12	+ 5	−61	+18	−40	−24	−24	− 3
Grayling, Mont.	− 9	+13	−47	+ 5	−60	− 1	−21	+ 7	−31	+20
Border, Wyo.	− 3	+28	−33	+ 3	−60	−12	−50	−12	−42	−12
Moran, Wyo.	−55	+ 5	−16	− 4	−63	− 9	−52	0	− 7	+16
Riverside Ranger Stn.	−57	− 2	−46	− 3	−66	− 3	−31	− 3	− 9	+ 9
Parshall, N. D.	−29	−16	−45	−23	−60	−24	−52	−28	−38	−14
Island Park Dam, Ida.	−32	−26	−18	+ 4	−60	− 5	−32	+ 7	+ 1	+25
Taylor Park, Colo.	+20	+27	−10	+20	−60	+ 3	−38	+21	+15	+29

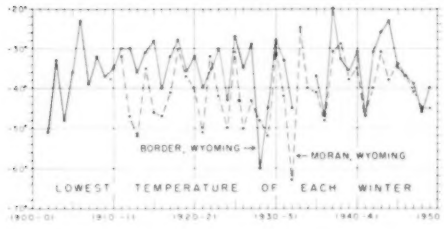

Fig. 2. The lowest temperature of each winter for Moran and Border, respectively.

From the available information on these 10 cases, it appears that very special local circumstances are required to push the thermometer that low. On February 8, 1929, when Border reached −60°, Moran had only −48° and Riverside −50°. Four years later, on February 9, 1933, when Riverside set the all-time record of −66° and Moran had −63°, Border (125 miles farther south) recorded a mere −28°, but −45° occurred there the next day. These contrasts are shown by the accompanying comparison of lowest temperatures at Moran and Border (Fig. 2).

At both Moran and Border, the observed

frequencies of winter minima (blocks in Fig. 3) roughly follow the frequencies predicted by the statistical theory of extreme values (solid curves in Fig. 3). If climatic conditions during the next 1,000 years do not change from those of the past half century, temperatures of −60° or colder should occur about 37 times at Moran and about 16 times at Border. Consequently, the average interval between such temperature extremes should be about 27 years at Moran, 63 years at Border. However, about half of the actual intervals between such temperatures will be less than two thirds as long as these average intervals: 18 years at Moran, 42 at Border. At either place, readings of −60° or lower in two consecutive winters are not improbable, if and when local conditions combine favorably.

The exact local conditions favoring extremely low temperatures cannot be determined with any precision without detailed information on the meteorological situations at the times of occurrence. In general, these extreme temperatures probably occur when cold air, after advection and stagnation, is further cooled locally by radiation, draining into the point of observation. Since the original air mass is very extensive, and radiative conditions are similar over extensive areas, unique local conditions of air drainage must cause the exceptional low temperature readings. The diversity of the 10 places which have recorded temperatures of −60° or colder indicates that air drainage conditions are extremely variable.

It is impossible to predict where or when such very low readings will occur in the United States, other than that they are most likely in the first half of February in valleys in the Yellowstone Park area, but they may occur in January as well, and can happen anywhere in the central and northern Rocky Mountains or on the adjacent plains to the east (Fig. 1). With the constantly increasing number of weather stations, especially at higher elevations, the next half century may see far more than the 10 readings which the United States has experienced in the past 65 years. Nevertheless, such occurrences are very local and isolated.

On the days when a single station records a temperature of −60° or lower, some other places in the same general area, but not all of them, have temperatures below −50°, with a few approaching −60°. Thus, for practical purposes, the lowest air temperature, five feet or so above the ground, which may reasonably be expected anywhere in the United States is no lower than −60° F.

This article is published with the approval, but not necessarily the endorsement, of the Department of the Army. Much of the research for the data presented above and in the following notes was done by O. S. Parmele, statistical clerk. Unless otherwise indicated, all quotations in the notes are from *Climatological Data for the United States by Sections*, for the appropriate month and section.

NOTES ON THE 10 LOWEST U. S. TEMPERATURES

The lowest temperature. February, 1933, the month of the all-time United States record of −66° in Yellowstone Park and of −63° at nearby Moran, was one of abnormal weather. In Idaho, "This was the coldest February since the beginning of statewide records in 1894." At Tetonia, 30 miles due west of Moran on the other side of the Teton range, −57° was reported. In Montana, "West of the Divide, previous low temperature records for February were broken at about 80 percent of the stations," but few records were broken in eastern Montana. Nineteen of the 104 stations in Montana "recorded the lowest temperatures in their history." The lowest reading was −52°, at three places.

In Wyoming, lowest temperatures were chiefly in the western part of the state, where "it was reported that sheep were frozen standing up in the Jackson Hole district," in the center of which is Moran, 200 feet from the east shore of Jackson Lake. In Yellowstone Park, −57° occurred at Buffalo Ranch. Riverside Ranger Station itself was near the western edge of the park, 600 feet south of the Madison River, and operated intermittently for 28 years before the record low temperature was observed. A few months later the station was moved, because of the relocation of a road, to West Yellowstone, a few miles southwest and on the Montana side of the state boundary.

For his regular 5 p.m. reading on February 9, 1933, A. J. Bicknell, the co-operative observer at Riverside, recorded on the monthly form (now in the National Archives) a minimum temperature of −65° with a note: "unable to register coldest." This statement was amplified under remarks: "Used Starrett caliper to read minimum on 9th. Reading was found a little over 66° below. Called it −65° to be on safe side."

Later, the original figure was crossed out and a −66° entered in red, presumably at the climatological center in Cheyenne. Thus Riv-

erside holds the official minimum temperature record for the United States, eclipsing the −65° at Ft. Keogh 45 years earlier.

Other low readings in Yellowstone Park area. Grayling, Montana, the first place to report −60° in this century, no longer exists. Its site along the Madison River a few miles west of Yellowstone Park is now covered by Hebgen Lake. The climatic record, from 1904 to 1912, has been merged with that for Hebgen Dam, 10½ miles northwest and 150 feet lower. P. Kerzenmacher, the observer at Grayling, recorded −60° on February 12, 1905, and remarked, "This month has been noted for cold clear nights and very warm and clear days and less snow than was ever known before." At this time in Idaho, −48° was recorded, while in Montana three stations had −50° or colder.

The second of these readings came in 1929. Wyoming had "the coldest February since 1899, and the absolute minimum, −60° at Border, was the lowest since State averages began in 1892." Border is about half a mile from the Bear River, in southwest Wyoming. In Idaho it was the second coldest February on record, and in Montana the third coldest February.

The last of these readings came in January, 1943. "The minimum temperature of −60° recorded at Island Park Dam in Fremont County on the 18th is the lowest officially recorded in Idaho since state-wide records began in 1893." Just to the east in Wyoming, "A new record minimum temperature for January was set when a temperature of −58° was recorded at Lamar Ranger Station on the 18th." In Montana to the north, "The extreme minimum temperature for the State, −58° at West Yellowstone on the 18th, equaled the previous low record for January."

The 19th-century readings. The extreme of −65° at Ft. Keogh, Montana, near present-day Miles City, may not have occurred on the date in 1888 indicated in the register (January 13th) which was authenticated by "E. A. Koerper, Surgeon, U. S. Army." It is possible that instructions were confused, and that when the self-registering thermometers were read, presumably at 7 a.m., both values were entered for the previous day instead of only the maximum. The Ft. Keogh register for January, 1888, shows:

Date	7 a.m.	2 p.m.	9 p.m.	Max.	Min.
12	−10°	−14°	−20°	−22°	−34°
13	−26°	−20°	−30°	−20°	−65°
14	−60°	−23°	−37°	−23°	−41°
15	−40°	−12°	−35°	−12°	−46°

While these figures do not inspire great confidence in the early reading of −65°, they do not discredit it; no other evidence has been obtained from other stations in eastern Montana.

The earliest of the 10 coldest United States temperatures was observed at Poplar River. "George A. Cardan, pvt, Signal Corps, U. S. A.," recorded readings of −63.1° on both the wet- and dry-bulb thermometers at 7 a.m. on New Year's Day, 1885. This Poplar River reading was later confused with the subsequent −65° at Ft. Keogh (see W. I. Milham, **Meteorology,** 1912, page 101, and T. E. Blair, **Weather Elements,** 1937 and 1942, page 287).

The third 19th-century reading was recorded by William Gaddis on February 11, 1899, at Ft. Logan, about 50 miles south of Great Falls. Of Montana's 51 stations, four, including Ft. Keogh, reported temperatures of −50° or colder during this month of widespread cold throughout all sections east of the Rockies.

Parshall and Taylor Park. Two of the −60° temperatures do not fit into the pattern of the other five in this century, all of which occurred near the Yellowstone Park area. Parshall, in North Dakota's flat farming country, is the easternmost and lowest place to have so low a reading, and Taylor Park is the southernmost and highest.

February, 1936, with an average temperature of −12.8°, was the coldest month of record in North Dakota, when most stations broke their low marks and some set records for continuous subzero days. Readings of −50° or lower were reported at 22 of the 79 stations in the state, with −56° registered at Berthold Agency on the Missouri River about 30 miles south-southwest of Parshall. In South Dakota, both McIntosh and Pollock had reported −58°. In Montana −50° or lower was registered at 24 of 41 stations in the eastern division, the lowest, −59°, at Frazer and Glasgow on the Missouri River. Five northern Minnesota stations and two places in northern Wisconsin reported −50° or colder. In Wyoming, however, the lowest this month was −48°.

The most recent low temperature record came at 7:30 a.m. on February 1, 1951, at Taylor Park, in the center of a narrow mountain valley about 100 yards wide, running east and west. "The instrument shelter is exposed on sod with no obstructions, such as high buildings and trees, in the area," the Weather Bureau section center reported. "The station had been inspected and the thermometers checked as recently as August 9, 1950." Although subzero temperatures prevailed throughout Colorado on the 1st, the second coldest temperature was only −49°, observed at three places. Of 35 stations within 100 miles of Taylor Park, only nine others had readings of −40° or colder. Altitude had little effect on minimum temperatures on February 1st, since of the 35 stations the other four above 9,000 feet had readings between −28° and −37°.

This latest reading climaxed one of the severest cold air outbreaks of the century, rivaling the famous freeze of February, 1899. In New Mexico, −50° was recorded for the first time in history, at Canjillon Ranger Station on February 1st. In Wyoming, −57° was recorded at Bondurant, and −50° at Moran, while −52° was reported in Montana at West Yellowstone.

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WEATHERCRAFT

Athelstan F. Spilhaus. The Viking Press, New York, 1951. 64 pages. $2.00.

THIS BOOK is aimed at an audience that was much neglected until recently — amateur weathermen of tender age. The past year has brought forth several books for the same group. The main emphasis of **Weathercraft** is on building a simple weather station from handy, everyday objects around the house. Observing the weather does not become scientific, says the author, until one makes actual measurements of the weather systematically.

Instructions are supplied for making over a dozen instruments. Some of these methods are well known, but Dr. Spilhaus has added several ingenious devices of his own that will be a delight to the gadget maker. All of the instruments were made by the author's son, who demonstrates their exposure and use in many illustrations.

For wind speed, always a problem for the amateur, Dr. Spilhaus shows how to take an old eggbeater and four small coffee measuring spoons to construct an anemometer that can actually be read in miles per hour. His thermometer is made from an electric light bulb and a drinking straw, while his barometer requires an old thermos bottle and a plastic straw. Much space is devoted to humidity instruments, as it should be, since water vapor plays such an important part in our health and comfort, yet is so difficult to comprehend and measure. In addition to the usual wet- and dry-bulb thermometers, Dr. Spilhaus has good working examples of a dew-point thermometer and also of a hair hygrometer. Another unusual item is a nephoscope, which should draw the attention of youngsters to the importance of observing the behavior of clouds.

All of these instruments should be built by science students in the classroom or as a home assignment. Not only will it be a good exercise in craftsmanship, but it will demonstrate the working of the basic principles that underlie our theories of meteorology.

The concluding portion of the book is a disappointment. In nine pages the author covers the subjects of logging observations, studying the weather map, and forecasting the weather. This section should easily be as long as or longer than the section on instruments, so that the student might have some guidance to carry on his observing program and to learn the rudiments of weather forecasting techniques. A weather map illustrating this section is out of date by 10 years and employs an outmoded

method of coding. The elaborate station model on the next page has no relationship to the code on the weather map and introduces some terms not explained in the text. It would have been much better to use a newspaper type of weather map, since these are available to most science classes. The three pages devoted to forecasting talk of cold fronts and warm fronts without any sketches or diagrams to give graphic illustrations of their structure.

One examines the book with the wish that there might have been a lot more than just 64 pages. Let's hope that Dr. Spilhaus plans a second volume that will explain to the same age group in the same simple manner the basic principles of weather behavior.

D. M. L.

WINTER STRIKES EARLY IN 1951

(Continued from page 131)

storms, and Portland, Maine, reported a fall of three inches in 24 hours. The wind in New England was very heavy, Logan Airport at Boston receiving sustained 43 miles per hour with gusts up to 65. Blue Hill Observatory south of Boston reported gusts up to 96 miles per hour, and at Bangor, Maine, gusts reached 74 miles per hour.

Floods and winds caused many power failures. A Northeast Airlines plane for Montreal returned to Boston when it was unable to land either at the Canadian city or at Burlington, Vermont, because of raging snowstorms. The New England storm death list reached 17, but nine Coast Guardsmen were rescued when their flying boat crashed as they attempted to aid two merchant ships in the Atlantic 690 miles southeast of Boston.

During the 5th a low pressure area took form over the Texas Panhandle on the western remnant of the polar front. By evening the center had moved into Arkansas (29.92 inches), and general precipitation commenced to the north. In the Ozarks region and northeastward through Missouri, it fell as snow, with many stations receiving their heaviest early season fall on record, and, in fact, most November snowfall records were eclipsed: Springfield, 16 inches; Nevada-El Dorado Springs area, 20 inches, and St. Louis, 12 inches. It was the heaviest fall on record for November and the heaviest in 24 hours for the past 39 years at St. Louis. Most of Missouri was snowbound on Election Day. The low moved north-northeastward in 24 hours to central Indiana (29.68 inches), bringing heavy rains to the Ohio Valley, snow to Illinois and Michigan, and freezing rain to Ontario and northern New York.

Along the Atlantic Coast the third major rainstorm of the week took place as a secondary disturbance developed over the mountains of the Carolinas at the apex of the cold and warm fronts. This moved rapidly northward inland to join the original center over New York State, and caused very heavy rains and southeast gales along the coast, with severe flooding in New England. Over three inches of rain fell in North Carolina, and New York City received 1.85 inches to swell the total for the week to 5.60.

After a stormy week the weather pattern changed rapidly. With the disappearance of the low trough in the United States, upper-air winds became more westerly, bringing maritime Pacific air into the central United States. The great equalizer of sports contests — the weather — was relegated to the bench, and football games on the weekend of the 10-11th were played under bright, mild, sunny skies in all sections except the Pacific Coast.

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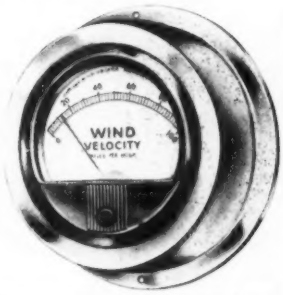

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TOTAL FLOOD DAMAGE

The Army Corps of Engineers recently released a documented record of last July's flood in the Missouri and Kansas area. It was the nation's worst flood disaster, with the total damages listed at $870,245,000.

The study said that the flooding, which began in May and reached its climax in July, inundated 2,256,300 acres, seriously affected 183 towns and cities, forced evacuation of 87,366 persons, destroyed 2,533 homes and flooded 24,893 more. It destroyed the structures of 354 business concerns and inundated an additional 3,889, flooded 251 churches and schools, and cost the lives of 18 persons. Losses to the industrial areas of Greater Kansas City totaled $363,000,000.

The above figures do not include the heavy damage in the nearby Arkansas River watershed in Kansas.

USWB CORRESPONDENCE COURSES FROM PENN STATE

The U. S. Weather Bureau seeks to provide a full curriculum at the college level for home study by its employees. Therefore, the Mineral Industries Extension Services of The Pennsylvania State College has expanded its correspondence courses in meteorology, developed by staff members of the meteorology division under the direction of Dr. Hans H. Neuberger. All of these courses are open to the public, but for some of them there are certain prerequisites.

In the new Weather Bureau program, the following previously listed college credit courses are included, all under the title **Meteorology:** 310C, general meteorology; 315C, 316C, 317C, synoptic meteorology exercises, I, II, III; and 372C, physical climatology. Four new courses have been added to provide a well-rounded program of study: 340C, physical meteorology; 350C, dynamic meteorology; 360C, meteorological instruments and observations; 373C, dynamic climatology. Each of the above courses consists of 24 assignments, earning three college credits, and costing $27.00 with required books additional.

Of special interest to amateurs are three elementary courses, also under the general title **Meteorology**: 300C, weather and man; 900C, a practical course in weather; 901C, practical exercises in elementary meteorology. There are no prerequisites for these courses. The fees are $18.00 for 300C, and $9.00 each for 900C and 901C.

For full information, communicate with Director D. C. Jones, Mineral Industries Extension Courses, The Pennsylvania State College, State College, Pennsylvania.

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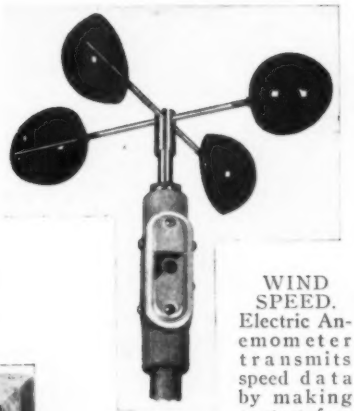

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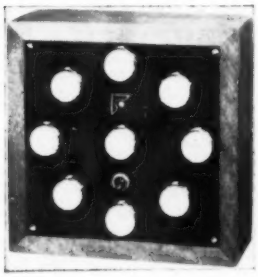

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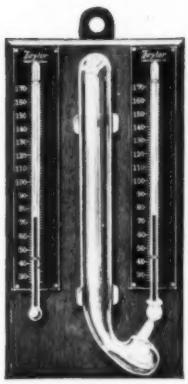

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